Research Note

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MORTALITY IN SECOND-GROWTH STANDS OF THE WESTERN WHITE PINE TYPE

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Foresters generally accept without alarm the normally small but continuing losses caused by the indigenous agents of mortality in forest stands. When a stand suffers a sudden increase in the rate of mortality, however, attention is focused upon the subject and a host of questions and speculative answers arise. How much growth is nullified by mortality during a rotation? What are the causes of mortality and how important is each one? Is there any relationship between the cause of mortality and the age, density, composition, or other qualities of the stand? How much mortality might be salvaged under intensive management? These questions and others have been voiced many times by foresters working in the western white pine type. However, accurate quantitative information has been lacking and such questions have largely gone unanswered.

Assembly of accurate mortality data is difficult and time-consuming. Growth studies, for example, based on temporary plots will yield reliable information; mortality data collected from the same plots will be inadequate because of the difficulty of determining the date and cause of death of the trees. Long-time permanent plot observations are needed for mortality studies. This report is based upon a study of data from repeated observations on permanent sample plots.

DATA USED

The data were gathered on 38 permanent sample plots in uncut second-growth stands. Length of record for individual plots ranged from 5 to 30 years with an average of approximately 20 years. Remeasurement of these plots at 5-year intervals made available data from 145 5-year measurement periods. Twenty-four of the plots, mostly 1 or 2 acres in area, were established to study growth and yield. The remaining 14 plots are uncut checks for various thinning tests and are one-half acre or less. The trees are individually numbered; thus each tree that died was accurately identified. At each remeasurement, trees which had died since the previous remeasurement were examined to determine the cause of death.

These plots were essentially free of mortality caused by white pine blister rust and white pine pole blight. The following results, therefore, presumably represent the "normal" mortality in western white pine stands.

RESULTS AND DISCUSSION

Although the mortality was extremely variable, the following generalizations may be made: Correlation analyses disclosed that the volume lost increased with age and volume of stand. In addition, board-foot mortality, but not cubic-foot volume or basal-area mortality, increased with improvement in site index. Table 1 shows the correlation coefficients which resulted from the analyses.

Table 1. Correlation of mortality with stand conditions

Measure of mortality	Correlation coefficient[1/] of mortality with stand			
	Density	Age	Volume	Site index
Basal area	+.213*	+.385**	+.413**	-.061
Cubic-foot volume	-.137	+.441**	+.457**	+.158
Board-foot volume	+.102	+.709**	+.756**	+.302**

1/ The correlation coefficient is a measure of the association of the values of the two variables being considered; the larger the correlation coefficient, disregarding the sign, the higher the correlation between the variables. A single asterisk (*) indicates significance at the 5-percent level, a double asterisk (**) significance at the 1-percent level; the odds are 19 to 1 and 99 to 1, respectively, that the values obtained are not due to sampling errors.

The size of the correlation coefficients in table 1 as well as partial correlation analyses show that, of all factors considered, volume is the most important stand characteristic influencing mortality. Because age and stand volume are closely correlated, age is also positively correlated with mortality. The possibility that older trees may be more susceptible to mortality due to their greater height, and the possible weakening of bole and root structure by rot fungi, may contribute to the increase of mortality with age.

The correlations of board-foot mortality with age and volume are high compared to those for cubic-foot volume and basal-area mortality. This is due to the fact that board-foot mortality depends upon the presence of trees of a certain minimum diameter, whereas trees of all diameters contribute to cubic volume and basal-area losses. The first trees to reach board-foot size are the most vigorous trees in the upper crown level and are therefore least likely to suffer mortality. As the stand grows older and the volumes increase, more trees, some of which are in the lower crown classes, attain board-foot size. Thus with increasing age and increasing board-foot volume, a saw log stand slowly changes from one composed of many vigorous trees to one with a steadily increasing proportion of less

vigorous trees. On the other hand, all trees, regardless of vigor, size, or age, and regardless of stand volume, contribute to mortality in terms of basal-area or cubic-foot volume.

How much volume is lost during the growth of a stand to maturity? A graphical analysis was used to give curves of net and gross growth[1/] by 10-year age classes. This analysis was based on the assumption, made necessary by the absence of data for stands younger than the 30-year class, that no mortality occurs before a stand reaches 30 years of age. The convergence of the curves of net and gross growth showed that this assumption is essentially correct. Table 2 gives cumulative mortality and cumulative gross growth obtained by this method. At 100 years of age, 10 percent of the board-foot volume produced during the life of the stand had been lost to mortality, leaving a stand of 35,380 board feet per acre. The same stand had lost 22 percent, or 2,540 cubic feet, of the total 100 years growth and 30 percent, or 116 square feet, of the basal-area production. These losses are not as great as many foresters had thought them to be. However, mortality may increase rapidly in stands over this age. Data which have been gathered on only one plot indicate this possibility.

Table 2. Cumulative gross production and mortality per acre

Age of stand	Square feet of basal area		Cubic-foot volume		Board-foot volume	
	Gross production	Mortality	Gross production	Mortality	Gross production	Mortality
30	86	0	990	0	180	0
40	152	5	1,940	50	680	0
50	204	16	3,320	230	3,380	400
60	247	33	4,830	500	8,080	800
70	286	53	6,400	870	14,480	1,400
80	321	75	8,010	1,340	22,080	2,200
90	355	95	9,650	1,900	30,480	3,100
100	389	116	11,310	2,540	39,380	4,000

How is this mortality which occurs during the first 100 years of the stand distributed by diameter class? How much is in trees of merchantable size? How much may be merchantable under intensive management? Naturally, in these young stands mortality occurred largely in small trees, but gradually the larger trees accounted for more of the losses until at 100 years of age only 20 percent of the total cubic-foot volume mortality was in trees less than 4.6 inches d.b.h. Slightly more than half was in trees from 4.6 to 10.5 inches d.b.h., material which is potentially merchantable for pulpwood and small saw logs under more intensive management. The 28 percent remaining was in trees over 10.5 inches d.b.h. which is the merchantable size at present for saw logs. In terms of board feet, two-thirds

1/ Gross growth as used here is net growth plus mortality.

of the volume was in trees over 10.5 inches d.b.h.; the other third included white pines from 7.6 to 10.5 inches d.b.h., and other species from 9.6 to 10.5 inches d.b.h.

Thus much of the mortality which occurred in the first 100 years of the stand's life was in trees of sizes now merchantable or potentially merchantable under conditions permitting more intensive utilization. However, an unknown amount of the mortality was beyond economic recovery due to its scattered occurrence.

Nearly half of the total mortality was due to wind and snow. Other important causes of death were insects, disease, and suppression. Table 3 shows the distribution of the total mortality by cause. An analysis of cause of death by age showed no trends, so all ages are included in the table. Changes in the relative importance of a specific cause of mortality when measured in different units indicate the size of tree generally killed by that agent. For example, suppression causes 25 percent of the basal-area mortality, 19 percent of the cubic-foot mortality, and 5 percent of the board-foot mortality. The small trees, with a low ratio of cubic feet or board feet to basal area, are those elements of the stand in which suppression tends to concentrate. Wind and snow percentages indicate that trees of all diameters are killed by these agents; insects apparently concentrate on the larger trees.

Table 3. Mortality by cause of death

Unit of measurement	Percentage of total mortality due to					
	Suppression	Wind and snow	Insects	Disease	Unknown causes	All causes
Basal area	25	46	5	9	15	100
Cubic-foot volume	19	47	8	10	16	100
Board-foot volume	5	45	19	12	19	100

Wind and snow, which cause heavy damage at irregular intervals, probably account for a large part of the variation in mortality. However, the very fact that these agents cause large irregular losses makes wind and snow of particular interest. Large volumes of down timber create problems of extreme fire hazards and possible buildups of destructive insects. By creating openings with disturbed soil they may also increase the expense of Ribes elimination.

The mortality studied here is probably similar to that which has been occurring for thousands of years in the western white pine type. The crude thinning which results, in conjunction with the ability of many of the

species in the white pine type to express dominance, has produced the present mature stands. Until economic conditions permit thinning operations in young stands, natural mortality will continue to provide crude thinnings at no cost to the forest manager.

SUMMARY

A study of mortality records collected on 38 permanent sample plots showed mortality to be extremely variable. However, mortality increased with volume and age of the stand, and in the case of board-foot mortality, with site index. At 100 years of age, 10 percent of the total board-foot production, 22 percent of the cubic-foot volume, and 30 percent of the basal-area production had been lost through mortality. Wind and snow caused nearly half of this mortality; suppression, insects, and diseases were other important causes of death. One-fifth of the cubic-foot mortality was in trees less than 4.6 inches d.b.h., material considered to be unmerchantable. Two-thirds of the total board-foot mortality was in trees now of merchantable size, i.e. 10.6 inches d.b.h. and larger. However, because of the small volumes per acre available for salvage annually, much of the mortality probably will never have economic value. Natural mortality provides very crude but inexpensive thinning of second-growth stands.